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JAN 1987

CITY OF HOLLAND (city of)

OTTAWA COUNTY, MICHIGAN

FEASIBILITY STUDY
FLOATING TIRE BREAKWATER
FOR
KOLLEN PARK

OCTOBER, 1986

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PREIN & NEWHOF
ENGINEERS — SURVEYORS
ENVIRONMENTAL & SOILS LABORATORIES

Michigan. Dept. of Natural Resources

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INTRODUCTION

This report has been authorized to investigate the feasibility of using floating tire breakwaters for Michigan projects receiving Michigan Waterways Division funding. It was commissioned to follow the Marina Development Study for Kollen Park, September 1985, because it is felt that site conditions at Kollen Park may determine that this type of structure is the most cost-effective for the breakwater proposed in the study.

In prior years, the Waterways Division had considered a floating tire breakwater at another site and completed a preliminary design. The project was not constructed nor has the Waterways Division followed the state of the art in the intervening time period. Floating tire breakwaters were very new when first considered by the Waterways Division. The study purpose is to obtain first-hand information on floating tire breakwaters during this time period.

The study scope includes research of all available literature on these structures, telephone contact and request for literature and operating data from owners and inspection of selected sites to interview the owners and obtain service data and photographs of the structures. Based upon this information, a preliminary structure type would be selected and performance data predicted. Cost information would be collected where available for the type of structure selected. The cost effectiveness of these breakwaters would be investigated with regard to service life and required maintenance.

If, as a result of this study, it appears that floating tire breakwaters are feasible for Michigan projects and if the City of Holland deems that a floating tire breakwater is aesthetically suitable and appropriate for this location, a preliminary plan for this project may be authorized or a design prepared for a test section of this type breakwater.

GENERAL INFORMATION

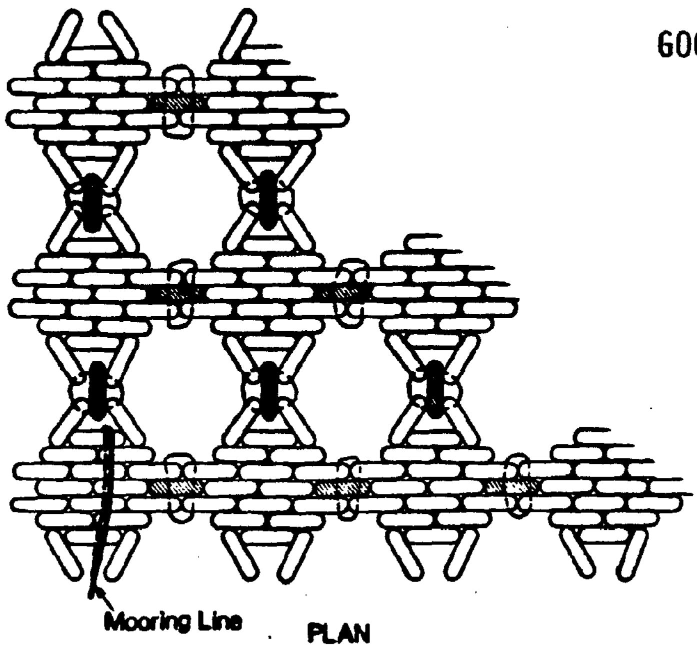
The initial investigation determined that there are three distinct types of floating tire breakwaters. They are the wave maze, the pipe tire and the Goodyear design. The initial research and investigation (Appendix 1) concluded that the Goodyear design merits further investigation.

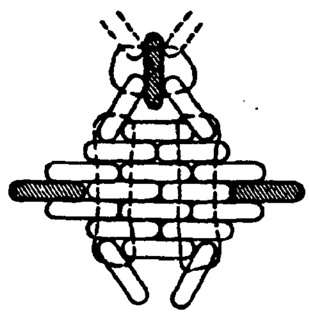
The Goodyear design (Figure 1 page 3A) consists of 18 tire modules connected together to create a breakwater of most any dimensions. The modules are connected by the same type of belting used to secure tires within the module. The breakwater is held in place by mooring lines connected to anchors to hold the breakwater in location. The windward anchors are typically much closer spaced or heavier than leeward anchors.

There have been many variations in the way floating tire breakwaters are constructed. Some have used truck tires because of their greater size and mass as opposed to automobile tires. All successful installations have used some type of foam for flotation. Conveyor belting has been the only relatively successful method of assembling and connecting modules. Steel or nylon bolts with various types of washers have been used for connecting belting. Mooring lines are chain, steel cable or nylon with anchors of stone, cast concrete, anchor drilled into rock, or piling.

GOOD YEAR DESIGN

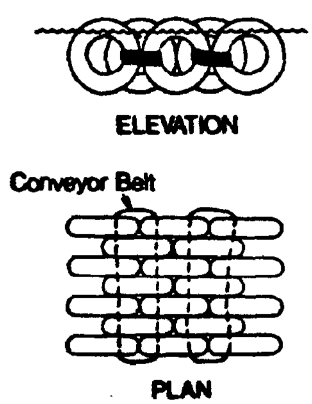
FIGURE 1





18 Tire Module Detail

Note: each tire equipped with some form of supplemental flotation, tires shown cross-hatched interconnect modules



H incident wave height

H_t transmitted wave height

L wavelength

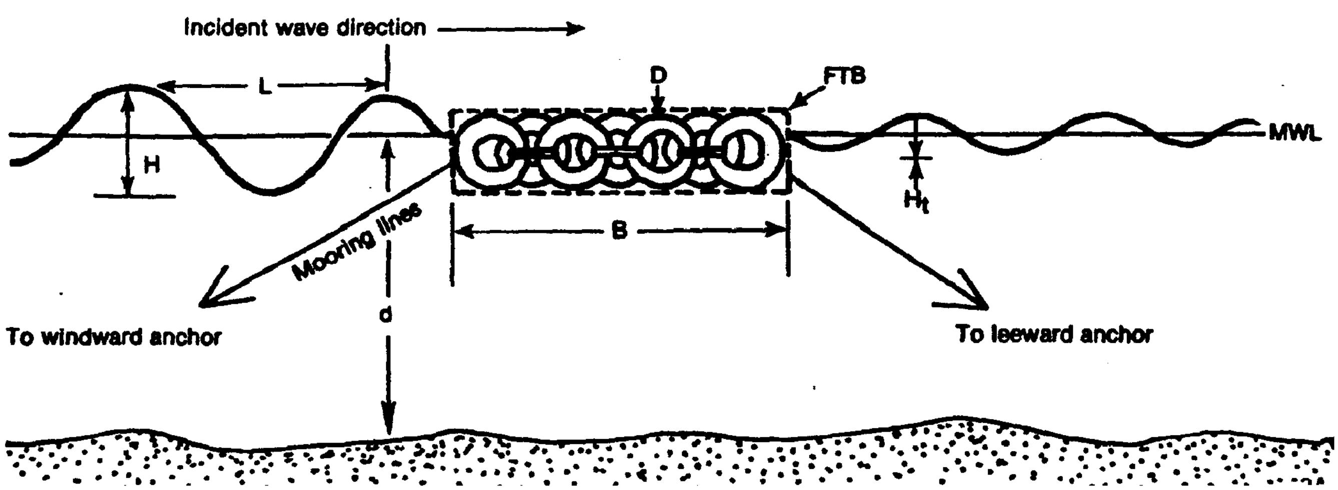
d water depth

MWL mean water level

D tire diameter

B beam size of FTB

H_t/H ratio of transmitted to incident wave height (C_t)



INSTALLATIONS INSPECTED

Floating tire breakwater installations visited were at Lorain, Ohio, Charlevoix, Michigan and Burlington, Ontario, Canada. Pertinent features of each design and owners comments are individually presented.

Lorain, Ohio

Lorain is situated on the south shore of Lake Erie approximately 30 miles west of Cleveland. The floating tire breakwater is located within the harbor at the outlet of the Black River. The floating tire breakwater is well protected except from the northwest. Winds from the northwest result in waves entering the harbor through the channel opening and reaching the breakwater at reported heights of as much as four to five feet.

The breakwater is approximately 90 feet wide and 600 feet long, containing 20,000 tires. It was constructed to protect 72 single point anchor moorings on the shore side. It is secured by 12 anchors on the lake side and 6 on the shore side. (Photos page 4A)

The owner reports that he feels the structure is 65 to 75 percent effective with regard to short period waves. Long swells go right through the breakwater but the chop is knocked off. Severe rocking of the boats moored behind the breakwater is experienced during storms. Only one claim for damages to a boat has been filed in five years. The claim was with regard to a broken mooring line.

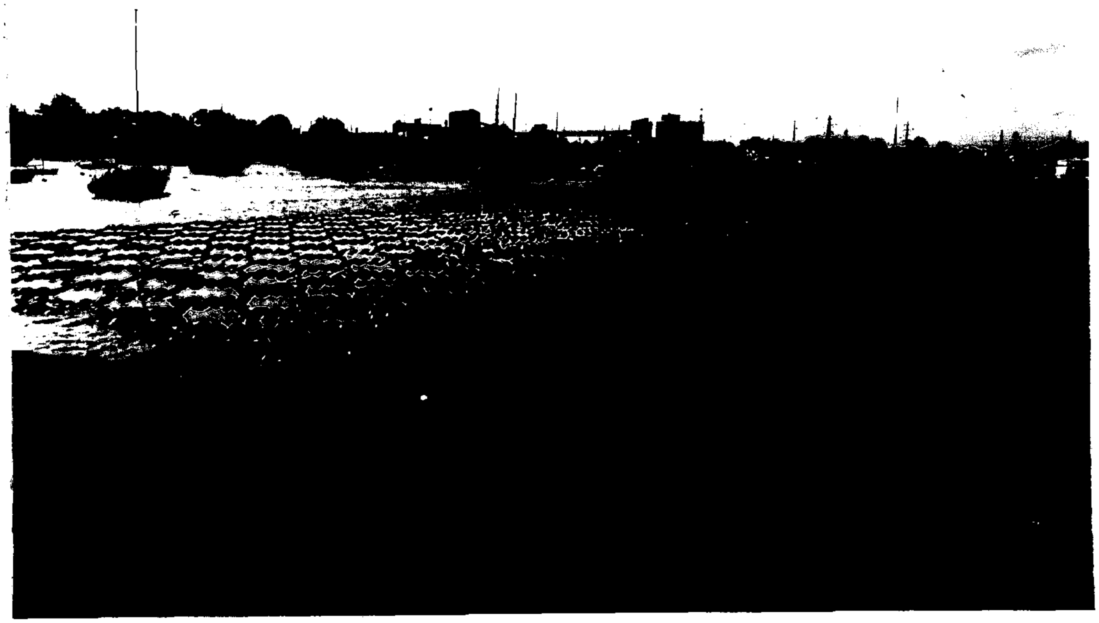


PHOTO TAKEN FROM EAST BREAKWATER LOOKING SOUTHWEST AND TOWARD SHORE - MOORING AREA ABOVE RIVER MOUTH IN BACKGROUND TO RIGHT

PHOTO LOOKING WEST SHOWING MODULAR CONSTRUCTION AND RELATIVE STRAIGHTNESS AND UNIFORMITY OF STRUCTURE.

The floating tire breakwater was installed with an anticipated service live of 7 to 10 years. After 5 years of service, it appears that the breakwater will survive its predicted life span.

A significant amount of maintenance is required annually. Maintenance is done during July and August when the lake is generally calm and water warm. In the summer of 1986, 4200 lineal feet of broken belts were replaced. This is approximately 14% of the belting. Belts break from chafing (rubbing against tires) and generally do not break where bolted together. Initially, some 1/4" thick belting was used for repairs which didn't last. Now only belting at least 3/8" thick is used. About 25 tires are lost and must be replaced each year.

Annual repairs of belting and replacing tires require approximately two months time of two men, a boat and light tools. Four-inch belting is used. It is cut to length with a hack saw and bolt holes drilled with an electric drill. Since the breakwater is covered with seagull dropping during calm weather, it is a disgusting job to replace the belts. If possible the repair work is done immediately after storms which clean the breakwater.

The breakwater was originally estimated to cost $44,000. The project was bid competitively and four bids were received which varied from $89,000 to $269,000. All bids were rejected and the port authority decided to build the floating tire breakwater in-house. The total cost of the breakwater was slightly over

$52,000. The breakwater was built with CETA labor. All belting used was donated and tires were provided and delivered to the site at no cost.

Maintenance costs are approximately $5,000 a year for labor and tools. All belting is donated annually by the Goodyear Company because of their continued interest in the project. Replacement tires, of course, are available free of charge from any number of suppliers.

<u>Charlevoix, Michigan</u>

The floating tire breakwater is located at the Irish Marina on the south side of Lake Charlevoix near the west end of the lake. The location is well protected from all but an east wind. Maximum wave conditions with an east wind are observed to be about three feet. The floating tire breakwater is used as a breakwater on the east and northeast sides of the marina. The floating tire breakwater is approximately 30 feet wide outside the outer head pier which is also supported on floating tires. All head piers in the marina are constructed on floating tires while the floating finger piers are on foam billets. The marina contains 60 slips. The floating tire breakwater is anchored with 160 modified Danforth anchors. The anchors were originally installed by a diver. It is also held in place during the summer by piling for the finger piers which is driven each spring and removed in the fall. (Photos page 6A, 6B)

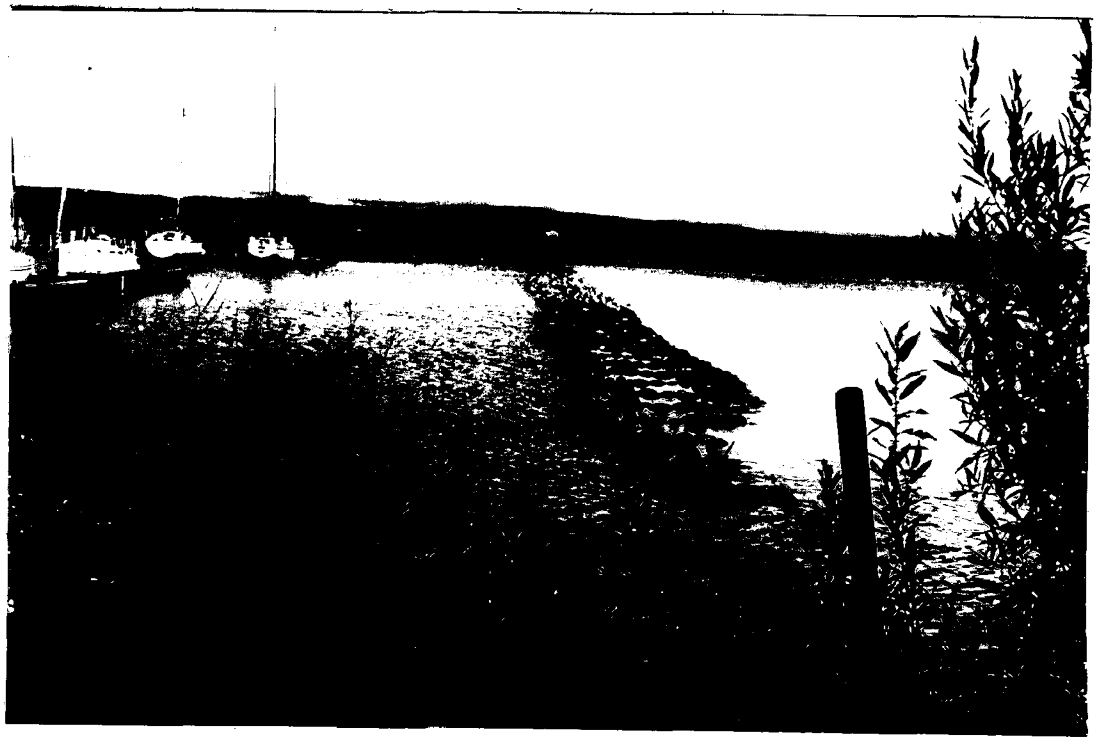
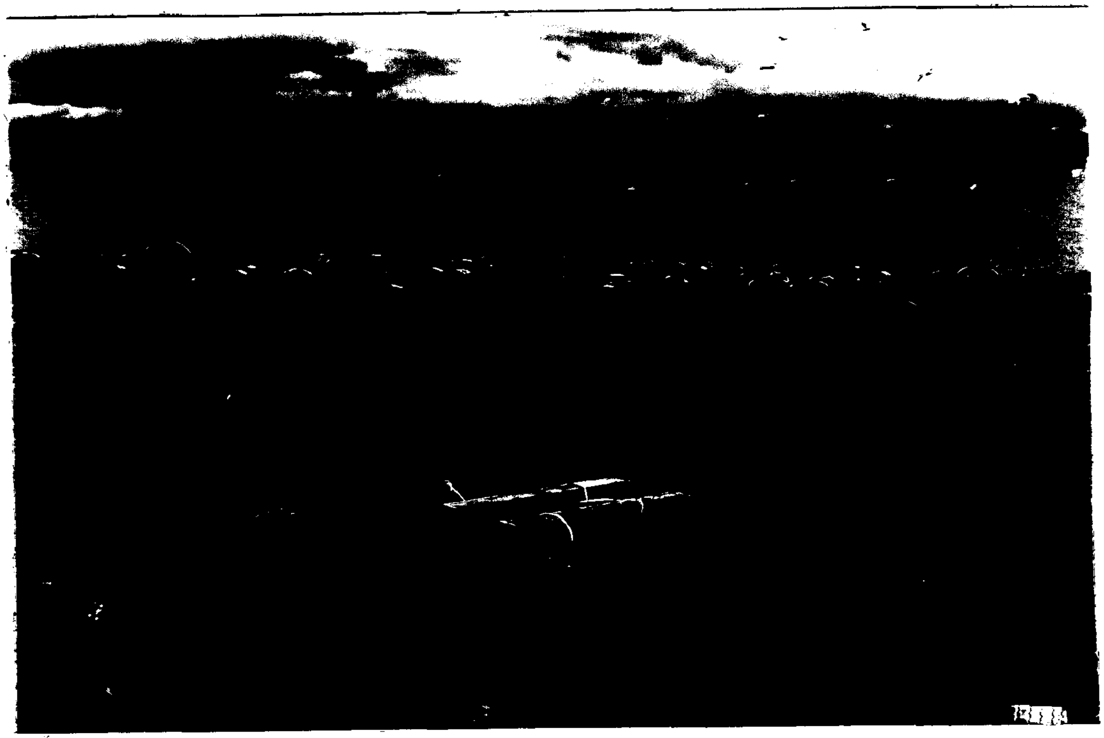


PHOTO LOOKING NORTH SHOWING EAST BREAKWATER FOREGROUND AND NORTHEAST BREAKWATER BEHIND.

PHOTO LOOKING EAST ALONG OUTER HEAD PIER - NOTE HOW SOME OF THE ORIGINAL TIRES INSTALLED ALONG PIER ARE PARTIALLY SUNK DUE TO LOSS OF FLOTATION



NORTHEAST CORNER - BREAKWATER PROTECTING HEAD PIER SHOWING NAVIGATION LIGHT

PHOTO SHOWING HEAVY BELTING USED TO CONNECT MODULES

The breakwater is mostly constructed with truck tires. Tires are partially filled with a two-component polyurethane foam. The foam is not a closed cell foam and has gradually become saturated causing some of the tires to sink. In some time period, the amount of flotation lost will require a major rehab project.

The head piers consist of 40 foot connected modules, 12 foot wide, supported upon 12" steel channel sides with a steel beam on centerline and 2 x 4 nailers between. Deck is 2 x 8 wolmanized lumber. The owner feels supporting head piers on floating tires was a mistake and if he were to build again would use foam billets for pier support. The marina and floating tire breakwaters are protected by a bubbler system during the winter. Each year additional lines are added to upgrade the system. The primary objective of the bubbler system is to keep the ice in the marina and breakwaters isolated from the lake ice. This has been quite successful in recent years, although significant damage resulted from ice conditions shortly after the marina was constructed.

No costs were quoted for the breakwaters which were constructed by the marina's staff during the winter. Maintenance of the breakwaters is estimated to be $3,000 a year and consists mainly of hiring divers for about two days per year to tighten up anchor lines. The anchor lines were originally installed at a slope of about 1 on 7. The anchors are slowly dragging and to keep the breakwater in place the lines must be shortened. The present slope is now approximately 1 on 3. The anchors will probably have to be replaced within a few years at which time gravity anchors will probably be used. The owner estimates that the breakwater reduces three foot waves to about 1 foot and knocks the chop off swells. He has observed that without floating tire breakwater protection that the boats rocked violently during storms from the east. After installation of the breakwater in its present configuration, the boats still rock but at a slower and more tolerable rate.

Burlington, Ontario

The Burlington breakwater is located at the LaSalle Park Marina, Burlington, Ontario, Canada near Toronto on Lake Ontario. It was built in 1981 at a bid price of $3.70 a square foot Canadian. It is located in an area of moving ice. The entire breakwater is, therefore moved into a protective slip in the autumn and back in place in the spring. This has been the only maintenance cost to date. (Photos page 9A)

PHOTO OF OUTSIDE BREAKWATER

PHOTO OF ENTRANCE BREAKWATER

CONSTRUCTION APPROACH

Floating tire breakwaters have been constructed by contractors on a competitive bid basis. They have also been constructed by owners with volunteer and subsidized labor. Old automobile tires are available free or sometimes for the cost of hauling. It is often necessary to pay a modest price for old truck tires. The major cost of an installation seems to be the anchorage which is dependent upon water depth and bottom conditions. It appears that if a community is willing to collect tires, purchase belting and other materials, hire local labor, provide construction management of the project and administrative services, that a floating tire breakwater can be constructed at a significantly smaller cost than by taking competitive bids from contractors. This is because of the difficulty in a contractor estimating the effort to collect the tires and accurately estimate labor requirements. Very few contractors are experienced in constructing floating tire breakwaters.

COST EFFECTIVENESS

The costs of floating tire breakwaters built to date have varied widely because of the methods used for their construction and water depth and anchorage conditions at each site. It is felt that a floating tire breakwater can be constructed in a cost range of approximately $4 to $7 per square foot for a community project and $7 to $10 per square foot for a contracted project.

The cost of a floating tire breakwater is a small fraction of the cost of a conventional breakwater, especially at locations of deep water depths or soft bottom conditions. The average life of a floating tire breakwater constructed using current technology is probably in the 7 to 10 year range. Maintenance costs should be budgeted at about 10% of the cost of the original installation realizing that some year maintenance costs will be nil and other years ice damage could result in substantial repair costs.

HOLLAND APPLICATION

A floating tire breakwater may be feasible for the marina proposed at Kollen Park. It is felt that a structure 60 feet wide would reduce waves to approximately one-third of their height. Since bottom conditions are poor, construction costs will probably be on the high side of average. Breakwater costs are estimated to be:

Community Project	$550,000
Contracted Project	$850,000

Maintenance costs are estimated at about $60,000 for the average year. These estimates are based upon the availability of a sufficient number of tires at no cost and the purchase of all other material.

It appears that installation of a floating tire breakwater at Kollen park will reduce waves sufficiently to allow installation of floating piers between the breakwater and shore. It also appears that the proposed structure has sufficient chances of surviving ice conditions at the site to warrant the cost of installing a test section. Installation and monitoring of a test section is the next logical step before committing the funds to install the entire floating breakwater. If a decision is made to proceed with testing, other types of floating breakwaters could be investigated at the same time.

Although the breakwater appears to be feasible in the physical sense, it is less than attractive economically. Even through its cost is a fraction of the cost of constructing a fixed breakwater, its design life of 10 years is only a fraction of the life of a fixed structure which may last in excess of 100 years. In addition, annual maintenance is time consuming and represents an ongoing, expense which is not the case with a property designed fixed breakwater.

A permit will be required for the breakwater. The environmental effect of a floating tire breakwater will have to be addressed. Negative factors include loose tires and belting breaking free, a slippery moving surface and seagull attraction. Positive features are the floating breakwater does not cut off lake currents and it may be good for fish.

A P P E N D I X   I

PRELIMINARY RESEARCH

September 3, 1986

Dear Mr. Prein:

In compliance with your instructions during our recent meetings regarding the development of floating tire breakwaters (FTB's) I have reviewed existing literature, reviewed design with engineers who have developed plans for such structures and discussed construction thereof with individuals who have developed them. Following is what I have learned which should be of value in establishing the feasibility of using a floating tire breakwater at a specific site.

A. Types of FTB's - There are three distinct types of FTB's. They are the wave maze, the pipe-tire and the Goodyear. The wave maze is a patented configuration and, as far as I know, has been used sparingly. I have seen the installation in San Francisco Bay. It suffered severe damage during a storm. A pipe-tire breakwater was installed on Long Island Sound more than 5 years ago. I have been unable to get any information on the success or failure of this installation. The Seattle District, Corps of Engineers, conducted a floating breakwater prototype test on two floating breakwaters in Puget Sound. One of the breakwaters was construction of reinforced concrete. The other was a pipe-tire breakwater. The results of this experiment have been published by the Corps in Miscellaneous Paper CERC-86-3.

The third type of FTB is known as the Goodyear because it was designed and promoted by that rubber company. This design comprises over 90% of all FTB's constructed in the United States and there are well over 100 of them. The wave maze, since it is patented would, if built, require payment of a royalty. In addition I believe it is no more effective than the Goodyear and is more complex to construct. I therefore suggest that you do not give additional consideration to this configuration.

The pipe-tire is considerably more expensive than the Goodyear but is more effective in attenuating the incoming wave. In cases of restricted areas it might prove to be the better choice. In the case of Lake Macatawa, I believe there is sufficient clearances to permit primary consideration of the Goodyear.

B. Publications - There are literally dozens of publications on FTB's. I have examined as many of these as I have been able to obtain. Many are obsolete or have proved invalid by subsequent experience. There are, however, several which should prove of considerable value should the decision be made to pursue development. They are as follows:

1. "Constructing A Floating Tire Breakwater - The Lorain Ohio Experience" by D. Thomas Lee, 2200 West Erie Avenue, Lorain, Ohio 44052. Available from the Lorain, Ohio Port Authority.

2. "Design and Construction Manual for Floating Tire Breakwaters", by Craig T. Bishop. Available from Hydraulics Division, National Water Research Institute Canada Centre for Inland Waters, 867 Lakeshore Road, P.O. Box 5050, Burlington, Ontario, Canada, L7R4A6.

3. "Guidelines for the Effective Use of Floating Tire Breakwaters, " by Bruce DeYoung et al. Available from the Distribution Center, 7 Research Park, Cornell University, Ithaca, New York 14850.

4. "Wave Transmission and Mooring Force Characteristics of Pipe Tire Floating Breakwaters", by Harms and Westerink. Available from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161.

5. "Floating Breakwater Prototype Test Program: Seattle, Washington", by Nelson and Broderick. Available from U.S. Army Waterways Experiment Station, Coastal Engineering Research Center, P.O. Box 631, Vicksburg, Mississippi 39180-0631.

I am still searching for additional publications to review and may wish to add to the list in the near future.

C. Existing FTB's - There are many FTB's located throughout the United States. There are three in the Great Lakes Area which, I believe, should be visited by yourself and representatives of your clients. There are as follows:

1. Lorain, Ohio - This is a Goodyear FTB which was built five years ago by the Lorain, Ohio Port Authority. A careful journal was maintained during the construction period and a report, mentioned above, was prepared and presented at the 1982 Docks and Marinas Conference at the Madison Campus of the University of Wisconsin. The breakwater is performing well but requires regular maintenance. A visit to the site and a discussion of the advantages, disadvantages, effectiveness and maintenance costs with Mr. John Sulpizio, Director of the Lorain, Ohio Port Authority, should be of considerable assistance to you and your clients in assessing the feasibility of such a development in Lake Macatawa.

2. Charlevoix and Harbor Springs, Michigan - About six years ago, Mr. David Irish of Irish Boat Works constructed a Goodyear FTB on Lake Charlevoix. It is functioning well but, as in the case of Lorain, Ohio, requires regular maintenance. Last winter he constructed another Goodyear FTB on Little Traverse Bay in Harbor Springs. I believe that viewing both of these structures, discussing them with Mr. Irish and, in particular, determining what changes he made in the Harbor Springs installation as a result of his years of experience with the installation at Charlevoix would be very educational.

3. Burlington, Ontario, Canada - This is a Goodyear FTB which was developed under the guidance of Mr. C.T. Bishop of the National Water Institute, Canada Centre for Inland Waters. It is located on Lake Ontario. Mr. Bishop conducted much original research on FTB's and has published many papers on the subject. Although he no longer does research, he continues to monitor FTB installations and does consulting work on the subject. A visit with Mr. Bishop and an examination of the Burlington installation, I believe, would be of considerable value. I talked to him by telephone last week and he

is sending me some publications which should fill some gaps in my FTB library. Incidentally, I am leaving on a camping trip next week which will take me to many Canadian cities. Toronto, which is very close to Burlington, is on my itinerary. If you wish, I can visit with Mr. Bishop and examine the site during my stay in Toronto. I can then provide you with a report upon my return.

D. General Observations - From personal experience and from reviewing available publications I have suggestions, questions and general observations. They can be placed in no particular category so I shall list them randomly, as follows:

1. It is generally accepted that any reasonably sized FTB can not adequately attenuate an incident wave larger than 3 feet.

2. Stationary ice does not damage FTB's. Moving ice does damage them.

3. Many FTB's have been built on the ice and then simply been permitted to settle into position when the ice melts. It precludes the necessity for using floating plant to move the breakwater into position and simplifies positioning of the structure.

4. Where moving ice is a problem, it has proved effective to disconnect the FTB and float it into a protected Area in the autumn and return it in the spring. Where the mooring facilities are vulnerable to ice damage, this is not an acceptable maneuver.

5. I've seen it stated in one of the publications that steel belted tires should not be used because they are heavier and require more floatation. I wonder if this is so. The statement should be checked with a tire manufacturer.

6. Some consideration should be given to marking an FTB with lights since it could prove to be a hazard to navigation.

7. Every tire in an installation should be branded with an identifying mark. Otherwise certain, unjustified, liability problems may arise.

8. Urethane foam is inclined to break up under wave action or freezing and thawing cycles. Recent recommendations are to protect it. One method is to fill plastic bottles with foam and force the bottles into the tires. The problem of floatation should be discussed with Mr. Sulpizio, Mr. Irish and Mr. Bishop. With their extensive experience in maintaining these structures they may have better suggestions.

9. Truck tires, being less flexible than auto tires appear to hold the floatation material better. I believe that the tire least effective in holding the floatation material would be the radial since it is much more flexible than the bias ply tire.

10. I have seen the statement in some publications that floating breakwaters do not attenuate boat wakes as well as they do wind waves of comparable size and period. I find this difficult to understand.

11. Scrap conveyor belting in 3 to 4 inch widths seems to be the most effective way of connecting the tires. In fresh water, I do not think it is necessary to use the more expensive nylon nuts and bolts. I believe steel nuts and bolts should be satisfactory. Irish uses these, in 3/8 inch diameter with toothed washers.

12. All FTB's require regular maintenance.

E. Costs - There is little hard information on the cost of FTB installations. Many of them are built with volunteer labor, volunteered boats and volunteered trucks. Some are done using municipal forces. Few, if any, have been constructed by contract after competitive bidding. The experience for the Lorain, Ohio Port Authority is interesting. In 1981 they prepared a cost estimate for an 80 x 600 foot Goodyear FTB. The estimate was $63,100. They received bids ranging between $90,000 and $270,000. They therefore, decided to build the FTB in house using CETA labor which, including fringe benefits, was at a rate of $6.50 per hour. Supervision, including fringe benefits, was at a rate of $16.40 per hour. Total costs for a breakwater 80 feet wide by 600 feet long was $103,000 of which about 50% was labor and 50% was materials. In his report Mr. Sulpizio cautions the reader that many hours of time an much valuable equipment were loaned or donated to the project. The cost estimate is, therefore, of limited value. Mr. Bishop, in his 1980 report mentioned above estimates that the materials in a 100 x 55 foot section of Goodyear FTB would cost $5,400 or about a dollar per square foot. He feels that labor, under contract, would about equal the material cost. Adding 25% for supervision, overhead, profit and contingencies, the cost would be about $2.50 per square foot in 1980 figures. The cost of the Lorain project was $2.15 per square foot. Considering the fact that some time and equipment were loaned or donated to the Lorain project and that, as I recall, there was not much difference between the Canadian dollar and the U.S. dollar in 1980, the comparison was not bad. I hope that Mr. Bishop or the community can give us actual costs on the Burlington project if we have a meeting on the site.

F. Recommendations - Based upon the research described in the first paragraph of this letter I believe the development of an FTB in Lake Macatawa is physically and economically feasible. I suggest, however, that, if moving ice is a problem at the proposed location cost of maintenance and repair might prove prohibitive. I might wish to further qualify this statement after meeting with Mr. Sulpizio, Mr. Irish and Mr. Bishop.

September 30, 1986

I have reviewed the typed copy of my report which you sent me on September 15, 1986 and made a few minor changes.

As I promised in my report, I visited Mr. Craig T. Bishop, Coastal Engineer for Environment Canada at Burlington, Ontario on September 11, 1986. My visit with him reinforced my feeling that an FTB is feasible for the proposed marina on Lake Macatawa if moving ice is not a problem at the site.

Mr. Bishop has had extensive experience in the development and monitoring of FTB's and had many comments which I believe would be of considerable value should the Lake Macatawa project be pursued. The comments are as follows:

1. In the vicinity of Toronto there are two Goodyear FTB installations. One is at Burlington and one is at Belleville. In addition, an installation at Kingston is in the planning stage. Burlington was done in 1981 at a bid price of $284,000 (Canadian). It consisted of 1700 modules. Each module is approximately 45 square feet so that the price is about $3.70 per square foot which includes anchorage and tethering. Water depths at the site varied from 6 to 32 feet. The facility was built with auto tires, polyurethane floatation, concrete gravity anchors and chain tethering. The structures are located in an area of moving ice and are, therefor, moved to a protected slip in the autumn and back on site in the spring. The cost of removing and repositioning varies from $5,000 to $10,000 per year. No other maintenance has, to date, been required.

2. The Belleville installation was done in 1985 at a bid price of $115,000 (Canadian) and consisted of 2 Goodyear FTB's each 200 feet long by 40 feet wide. The cost therefor, was $7.18 per square foot or almost twice that of the Burlington project. The difference in the two prices is, in part, due to the fact that a third of the Belleville anchors had to be grouted into rock. Also mobilization costs were considerably higher.

3. It might be of value to ask Mr. Bishop for a bid tabulation after the Kingston bids are opened.

4. Auto tires are preferred over truck tires because they are easier to handle without mechanical equipment, are cheaper and easier to obtain.

5. A concrete floating breakwater costs about 10 times that of an FTB and requires considerable maintenance.

6. The mooring piers at Burlington are also floated on tires. The system consists of a single layer of tires placed horizontally and through bolted to deck framing. The tires are completely filled with polyurethane.

7. The Burlington and Belleville FTB's are marked by lights with solar powered batteries floating on horizontal foam filled tires. Fluorescent traffic cones are placed between the lights.

8. The big fixed cost in FTB's is in the anchorage. The wider the breakwater the lower the price per square foot.

9. Chain is the most popular tethering material although nylon line is coming into use. The advantage is that the flexibility of the nylon contributes to a reduction in the maximum design loads.

11. In foaming the tires for the FTB use about 1-3/4 gallons of polyurethane per tire. This is the amount used at Burlington, which has been in for 5 years, and they have had no problem with loss of floatation.

I believe that this report and that previously submitted should provide sufficient information to answer the questions which might assist you client in making a final determination. Please advise me if additional information is required.

Raymond Lawrence

A P P E N D I X   II

HOLLAND MARINA

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